3. Methane Emissions

Overview

U.S. Anthropogenic Methane Emissions, 1990-2001

	Methane	Carbon Equivalent
Estimated 2001 Emissions (Million Metric Tons)	28.0	175.8
Change Compared to 2000 (Million Metric Tons)	-0.3	-1.9
Change from 2000 *(Percent)*	*-1.1%*	*-1.1%*
Change Compared to 1990 (Million Metric Tons)	-3.7	-22.9
Change from 1990 *(Percent)*	*-11.5%*	*-11.5%*

U.S. anthropogenic methane emissions totaled 28.0 million metric tons in 2001, a decrease of 0.3 million metric tons from 2000 levels (Table 13). The decline in total methane emissions is primarily the result of a 0.2 million metric ton decrease in methane emissions from the natural gas system and a 0.2 million metric ton decrease in methane emissions from coal mining. These decreases more than offset a 0.1 million metric ton increase in methane emissions from landfills, the first increase in methane emissions from landfills in more than a decade.

While U.S. natural gas consumption dropped in 2001, gas production rose, reducing the need for gas withdrawals from storage and related methane emissions. At the same time, methane emissions from the ventilation and degasification systems in the Nation's gassiest mines also fell. Growth in methane emissions from landfills in 2001 is attributed to increased landfilling of wastes between 1998 and 2001 and a leveling off of previously increasing rates of methane recovery at landfills.

Estimated U.S. emissions of methane in 2001 were 3.7 million metric tons below the 1990 level, a decrease equivalent to 22.9 million metric tons of carbon, or 1.2 percent of total U.S. anthropogenic greenhouse gas emissions.[52] In addition to a 3.2 million metric ton decrease in methane emissions from landfills since 1990, there has also been a 1.4 million metric ton decrease in methane emissions from coal mines during the same period (Table 14). The 34.3-percent decline in emissions from coal mining is the result of a 143.9-percent increase in methane recovery from coal mines and a shift in production away from gassy mines. Overall, methane emissions account for about 9.3 percent of total U.S. greenhouse gas emissions when weighted by methane's global warming potential factor.

Methane emission estimates are much more uncertain than carbon dioxide emission estimates. Methane emissions usually are accidental or incidental to biological processes and may not be metered in any systematic way.[53] Thus, methane emission estimates must often rely on proxy measurements.

Estimated U.S. anthropogenic methane emissions for 2001 are based on incomplete data for several key sources; thus, the overall estimate is likely to be revised. Emissions from three of these sources—coal mining, natural gas systems, and landfills—represent three-fifths of all U.S. methane emissions. Thus, comparisons between 2000 and 2001 numbers are more likely to be valid in the context of directional change rather than magnitude of change. For example, because 2001 data on waste generation are not yet available, waste generation has been scaled to economic output as a proxy. Less critical but still important data are also unavailable for natural gas systems, such as miles of gas transmission and distribution pipeline.

[52]Based on a revised estimate of the global warming potential factor of 23 for methane. For an expanded discussion of global warming potentials, see Chapter 1.

[53]Wherever possible, estimates of methane emissions are based on measured data. In some cases, however, measured data are incomplete or unavailable. In the absence of measured data, emissions are indexed to some known activity data, such as coal production or natural gas throughput, and multiplied by an emissions factor derived from a small sample of the relevant emissions source or through laboratory experiments. For a more detailed discussion of where measured data were used and how emissions factors were developed, see Appendix A, "Estimation Methods." The absence of measured emissions data for most sources of methane emissions and the reliance on emissions factors represent a source of uncertainty (further details are available in Appendix C, "Uncertainty in Emissions Estimates").

Energy Sources

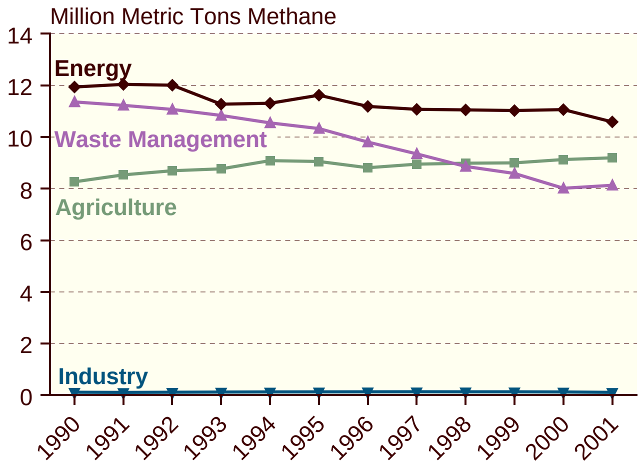
Principal Sources of U.S. Anthropogenic Methane Emissions, 1990-2001

Source	Million Metric Tons Methane 1990	2001	Percent Change 1990-2001	2000-2001
Energy	11.94	10.58	*-11.3%*	*-4.3%*
Waste Management	11.36	8.14	*-28.4%*	*1.4%*
Agriculture	8.26	9.19	*11.3%*	*0.7%*
Industrial Processes	0.12	0.11	*-4.1%*	*-11.7%*

U.S. methane emissions from energy sources were estimated at 10.6 million metric tons in 2001, 0.5 million metric tons lower than 2000 levels and 1.4 million metric tons below 1990 levels (Figure 3). The drop in methane emissions from energy sources since 1990 can be traced primarily to decreased emissions from coal mines and, to a lesser extent, to lower emissions from petroleum systems and stationary combustion.

Methane emissions from coal mines dropped by 34.3 percent (1.4 million metric tons) between 1990 and 2001. This decline resulted from the increased capture and use of methane from coal mine degasification systems and a shift in production away from some of the Nation's gassiest underground mines in Central Appalachia.

Figure 3. U.S. Emissions of Methane by Source, 1990-2001



Source: Estimates presented in this chapter.

Between 1990 and 2001, the share of coal production represented by underground mines declined from 41.2 percent to 33.3 percent. Methane emissions from petroleum systems dropped from 1.3 million metric tons in 1990 to 1.0 million metric tons in 2001. A decrease of 0.2 million metric tons in estimated emissions from stationary combustion made a smaller contribution to the overall drop in emissions from energy sources between 1990 and 2001. Together, the declines in emissions from coal mining, petroleum systems, and stationary combustion more than compensated for the increase of 0.5 million metric tons in emissions from the natural gas system, attributed to increasing U.S. consumption of natural gas between 1990 and 2001.

Coal Mining

U.S. Methane Emissions from Coal Mining, 1990-2001

Estimated 2001 Emissions (Million Metric Tons Methane)	2.8
Change Compared to 2000 (Million Metric Tons Methane)	-0.2
Change from 2000 *(Percent)*	*-6.8%*
Change Compared to 1990 (Million Metric Tons Methane)	-1.4
Change from 1990 *(Percent)*	*-34.3%*

The preliminary estimate of methane emissions from coal mines for 2001 is 2.8 million metric tons (Table 14), a decrease of 6.8 percent from the 2000 level.[54] This decrease can be traced to declines in emissions from the ventilation and degasification systems of underground coal mines, despite an increase in coal production levels, which rose by 4.4 percent in 2001 after falling for two consecutive years.

U.S. coal production rose from 1.07 billion short tons in 2000 to 1.12 billion short tons in 2001, returning to 1998 levels after two years of decline. Approximately three-fifths of the increased production was added to coal stocks rather than consumed. Between 1990 and 2001, methane emissions from coal mines dropped by 34.3 percent from the 1990 level of 4.22 million metric tons. The decline is attributed to three important trends: (1) methane recovery from active coal mines for use as an energy resource increased from 0.3 million metric tons in 1990 to about 0.7 million metric tons in 2001; (2) methane drainage from degasification in active mines decreased by more than 0.4 million metric tons between 1990 and 2001; and (3) methane emissions from

[54]Further details on emissions from abandoned coal mines are available in Appendix D "Emissions Sources Excluded."

ventilation systems at gassy mines dropped by about 0.6 million metric tons between 1990 and 2001 (Table 14).[55]

Natural Gas Systems

U.S. Methane Emissions from Natural Gas Systems, 1990-2001

Estimated 2001 Emissions (Million Metric Tons Methane)	6.1
Change Compared to 2000 (Million Metric Tons Methane)	-0.2
Change from 2000 *(Percent)*	*-3.9%*
Change Compared to 1990 (Million Metric Tons Methane)	0.5
Change from 1990 *(Percent)*	*9.1%*

At 6.1 million metric tons, 2001 estimated methane emissions from natural gas production, processing, and distribution were down from the revised estimate of 6.4 million metric tons for 2000 (Table 15). The 3.9-percent decline in emissions levels can be traced to a drop in gas withdrawals from storage and a decrease in the number of operating gas processing plants in the United States; however, the 2001 estimate is preliminary, because pipeline data for 2001 had not been finalized as of the publication of this report. The estimated 2001 emissions level is 9.1 percent above the 1990 level, with about two-thirds of the increase attributable to increased mileage of distribution pipelines and one-third attributable to increases in gas withdrawals.[56]

Petroleum Systems

Methane emissions from petroleum systems are estimated at 1.03 million metric tons in 2001, nearly unchanged from 2000 levels and down some 20.7 percent from 1.29 million metric tons in 1990. Domestic oil production in 2001 was approximately 80 percent of the 1990 level, accounting for the decline in methane emissions from this source. Approximately 97 percent of all emissions from petroleum systems occur during exploration and production. Of the 1.0 million metric tons of emissions annually from this source, 90 percent can be traced to venting, of which nearly half is attributable to venting from oil tanks (Table 16). A much smaller portion of methane emissions from petroleum systems can be traced to refineries and transportation of crude oil.

U.S. Methane Emissions from Petroleum Systems, 1990-2001

Estimated 2001 Emissions (Million Metric Tons Methane)	1.0
Change Compared to 2000 (Million Metric Tons Methane)	*
Change from 2000 *(Percent)*	*-0.2%*
Change Compared to 1990 (Million Metric Tons Methane)	-0.3
Change from 1990 *(Percent)*	*-20.7%*

*Less than 0.05 million metric tons.

Stationary Combustion

U.S. Methane Emissions from Stationary Combustion, 1990-2001

Estimated 2001 Emissions (Million Metric Tons Methane)	0.4
Change Compared to 2000 (Million Metric Tons Methane)	*
Change from 2000 *(Percent)*	*-5.7%*
Change Compared to 1990 (Million Metric Tons Methane)	-0.2
Change from 1990 *(Percent)*	*-26.8%*

*Less than 0.05 million metric tons.

U.S. methane emissions from stationary combustion in 2001 were 0.41 million metric tons, down by 5.7 percent from the 2000 level and 27 percent below 1990 levels (Table 17). Residential wood consumption typically accounts for about 87 percent of methane emissions from stationary combustion. Methane emissions are the result of incomplete combustion, and residential woodstoves and fireplaces provide much less efficient combustion than industrial or utility boilers. Estimates of residential wood combustion are, however, very uncertain (for further details, see Appendix C). The

[55]The EPA believes that a significant portion of methane recovery from coal mines should not be deducted from current-year emissions, because the gas is being drained from coal seams that will be mined only in future years, if at all. The relationship between estimates of emissions from degasification and estimates of gas recovery is under review and may be revised in the future.

[56]The EPA estimates that the companies participating in the Natural Gas STAR program together avoided emissions of more than 711,000 metric tons of methane in 2000 and 805,000 metric tons in 2001. Program participants report annually on emissions reductions achieved through such activities as equipment replacement, enhanced inspection and maintenance, and improved operations management. Participating companies may either use their own techniques to estimate reductions achieved or employ default values developed by the EPA and the Gas Technology Institute (formerly the Gas Research Institute).

universe of wood consumers is large and heterogeneous, and EIA collects data on residential wood consumption only at 4-year intervals in its Residential Energy Consumption Survey (RECS). The most recently published EIA data on residential wood consumption are from the 1997 RECS. Residential wood consumption for the years after 1997 is estimated by scaling the 1997 estimates to heating degree-days. Updated data on residential wood consumption for calendar year 2001 will be available from the 2003 RECS.

Mobile Combustion

U.S. Methane Emissions from Mobile Combustion, 1990-2001

Estimated 2001 Emissions (Million Metric Tons Methane)	0.2
Change Compared to 2000 (Million Metric Tons Methane)	*
Change from 2000 *(Percent)*	*1.1%*
Change Compared to 1990 (Million Metric Tons Methane)	*
Change from 1990 *(Percent)*	*2.0%*

*Less than 0.05 million metric tons.

Estimated U.S. methane emissions from mobile combustion in 2000 were 0.2 million metric tons, up by 1.1 percent from 2000 levels and 2.0 percent higher than the 1990 level (Table 18). Methane emissions from passenger cars have declined since 1990 as older cars with catalytic converters that are less efficient at destroying methane have been taken off the road. However, from 1993 to 1999, rapid growth in the fleet of light-duty trucks and the related increase in methane emissions offset the declines from passenger cars. Although the rapid growth in emissions from light-duty trucks ended in 2000 and their emissions have declined over the past 2 years, that small decline has been offset by an increase in emissions from residual and distillate fuel consumed in marine vessels.

Waste Management

Methane emissions from waste management account for 29 percent of U.S. anthropogenic methane emissions (Figure 3), down from 36 percent in 1990. Landfills represent 98 percent of the 8.1 million metric tons of methane emissions from waste management and remain the single largest source of U.S. anthropogenic methane emissions (Table 13). The remainder of emissions from waste management is associated with domestic wastewater treatment. Estimated emissions from waste management would increase if sufficient information were available to estimate emissions from industrial wastewater treatment (for further details, see box on page 41 and Appendix D).

Landfills

U.S. Methane Emissions from Landfills, 1990-2001

Estimated 2001 Emissions (Million Metric Tons Methane)	8.0
Change Compared to 2000 (Million Metric Tons Methane)	0.1
Change from 2000 *(Percent)*	*1.4%*
Change Compared to 1990 (Million Metric Tons Methane)	-3.2
Change from 1990 *(Percent)*	*-29.0%*

Due to record levels of municipal solid waste reaching U.S. landfills since 1998,[57] estimated methane emissions from landfills rose to 8.0 million metric tons in 2001, 1.4 percent above the 2000 level of 7.8 million metric tons but still 3.2 million metric tons (29 percent) below 1990 levels (Table 19). The dramatic decrease in methane emissions since 1990 is directly attributable to a 3.9 million metric ton increase in methane captured that otherwise would have been emitted to the atmosphere. Of the 4.9 million metric tons of methane believed to be captured from this source, 2.5 million metric tons were recovered for energy use, and 2.4 million metric tons were recovered and flared. While estimates of methane recovered and disposed of in both practices are drawn from data collected by the EPA's Landfill Methane Outreach Program,[58] there is less uncertainty in the estimate of methane recovered and used for energy. It is likely that estimates of methane flared are biased downward due to a lack of comprehensive industry data.

The rapid growth in methane recovery has resulted from a combination of regulatory and tax policy. The Federal Section 29 (of the Internal Revenue Code) tax credit for alternative energy sources, added to the tax code as part of the Crude Oil Windfall Profits Act of 1980, provided a subsidy roughly equivalent to 1 cent per kilowatthour for electricity generated from landfill gas. However, this

[57]"Nationwide Survey: The State of Garbage in America, 1999," *Biocycle* (April 2000) for years before 2000. Waste generation for 2000 estimated on the basis of annual economic growth.

[58]See web site www.epa.gov/lmop.

Methane Emissions from Industrial Wastewater Treatment

Industries generating high volumes of wastewater that includes large amounts of organic material are likely to generate methane emissions from the anaerobic decomposition of that organic material. Industries that fit this description include pulp and paper manufacturing, meat and poultry packing, and vegetable, fruit and juice processing. Determining total wastewater outflows, organic loadings, and the portion of anaerobic degradation of the loadings for each industry is difficult. Further, the emissions contribution of other industries is impossible to quantify at this time. Thus, EIA has chosen to exclude this emissions source from its estimates of overall methane emissions.

In its report, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000*, the U.S. Environmental Protection Agency (EPA), makes some assumptions about the level of anaerobic decomposition of organic wastes in wastewater for the three industries referenced above.[a] For those three industries, the EPA estimates more than 700,000 metric tons of methane emissions in 2000, an amount that would be four times EIA's current estimate of methane emissions from wastewater treatment and would be equivalent to 2.5 percent of total estimated U.S. methane emissions.

[a]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2000*, EPA-236-R-02-001 (Washington, DC, April 2002), web site www.epa.gov.

tax credit expired on June 30, 1998, and, absent a similar subsidy, the number of additional landfill gas-to-energy projects that are commercially viable may be limited.

Both the Senate and House versions of the comprehensive energy bill that went to conference committee in September 2002 contained new landfill gas-to-energy incentives under Section 29 and Section 45 of the Internal Revenue Code. According to the Solid Waste Association of North America (SWANA), a waste management trade association, the provisions in the existing bills provide insufficient incentives for the development of landfill gas-to-energy projects.[59] Senator Blanche Lincoln (D-AR) and Congressman Dave Camp (R-MI) have proposed a substitute amendment to the provision. At the time of this writing it is unclear what the ultimate legislative outcome of this issue will be.

Increases in methane recovery have also resulted from the implementation of the EPA's New Source Performance Standards and Emission Guidelines. These regulations require all landfills with more than 2.5 million metric tons of waste in place and annual emissions of nonmethane volatile organic compounds (NMVOCs) exceeding 50 metric tons to collect and burn their landfill gas, either by flaring or as an energy resource.

The total volume of waste placed in U.S. landfills increased between 1998 and 2001. Because of the time lag associated with the decomposition of wastes, methane emissions began to grow again in 2001 and are likely to continue to increase later in this decade. Throughout the 1990s, methane recovery for energy and flaring at landfills offset increases in methane generated from decomposition of wastes. Unless methane recovery from landfills continues to increase, the rising level of waste landfilled since 1998 will result in higher levels of methane emissions levels from this source in the future.

Domestic and Commercial Wastewater Treatment

U.S. Methane Emissions from Domestic and Commercial Wastewater Treatment, 1990-2001

Estimated 2001 Emissions (Million Metric Tons Methane)	0.2
Change Compared to 2000 (Million Metric Tons Methane)	*
Change from 2000 *(Percent)*	*0.9%*
Change Compared to 1990 (Million Metric Tons Methane)	*
Change from 1990 *(Percent)*	*14.2%*

*Less than 0.05 million metric tons.

With the U.S. population growing slowly, methane emissions from domestic and commercial wastewater treatment are estimated to have grown by 0.9 percent between 2000 and 2001 to 0.17 million metric tons. This is about 14.2 percent above the 1990 level of 0.15 million metric tons (Table 13). Methane emissions from industrial wastewater treatment are discussed in the box above.

Methane emissions from domestic and commercial wastewater treatment are a function of the share of organic matter in the wastewater stream and the conditions under which it decomposes. Wastewater may be

[59]See web site www.swana.org.

treated aerobically or anaerobically. If it is treated aerobically, methane emissions will be low. Under anaerobic conditions, methane emissions will be high. There is little information available on wastewater treatment methods. Data on flaring or energy recovery from methane generated by wastewater are also sparse. EIA believes that emissions from this source are relatively small, representing on the order of 0.6 percent of all U.S. methane emissions. Thus, emissions are estimated using a default per-capita emissions factor and U.S. population data.

Agricultural Sources

Estimated agricultural methane emissions increased slightly between 2000 and 2001 (from 9.1 to 9.2 million metric tons) due mainly to an increase in emissions from rice cultivation, as well as enteric fermentation and the solid waste of domesticated animals associated with continued growth in average cattle size. At an estimated 9.2 million metric tons, methane emissions from agricultural activities represent 32.8 percent of total U.S. anthropogenic methane emissions (Table 13). Ninety-four percent of methane emissions from agricultural activities result from livestock management. About 64 percent of these emissions can be traced to enteric fermentation in ruminant animals, and the remainder is attributable to the anaerobic decomposition of livestock wastes. A small portion of U.S. methane emissions result from crop residue burning and wetland rice cultivation.

Enteric Fermentation in Domesticated Animals

U.S. Methane Emissions from Enteric Fermentation in Domesticated Animals, 1990-2001

Estimated 2001 Emissions (Million Metric Tons Methane)	5.6
Change Compared to 2000 (Million Metric Tons Methane)	*
Change from 2000 *(Percent)*	*0.5%*
Change Compared to 1990 (Million Metric Tons Methane)	0.5
Change from 1990 *(Percent)*	*9.0%*

*Less than 0.05 million metric tons.

In 2001, estimated methane emissions from enteric fermentation in domesticated animals rose by 0.5 percent to 5.6 million metric tons (Table 20). Because cattle account for about 96 percent of all emissions from enteric fermentation, trends in emissions correlate with trends in cattle populations. While cattle populations were flat or somewhat declining in 2001 (with the exception of cattle on feedlots), average cattle size (excluding calves) reached a 22-year high in 2001. Animal size is a principal determinant of energy intake requirements, which relate directly to methane emissions. Emissions remain 9.0 percent above 1990 levels, principally due to 7.5-percent growth in average cattle size between 1990 and 2001.[60] Meanwhile, cattle populations have fluctuated in a cyclical pattern, settling in 2001 at levels very similar to those seen in 1990.

Solid Waste of Domesticated Animals

U.S. Methane Emissions from Solid Waste of Domesticated Animals, 1990-2001

Estimated 2001 Emissions (Million Metric Tons Methane)	3.1
Change Compared to 2000 (Million Metric Tons Methane)	*
Change from 2000 *(Percent)*	*0.3%*
Change Compared to 1990 (Million Metric Tons Methane)	0.4
Change from 1990 *(Percent)*	*14.6%*

*Less than 0.05 million metric tons.

Estimated methane emissions from the solid waste of domesticated animals increased from 3.07 million metric tons in 2000 to 3.08 million metric tons in 2001 (Table 21). This small increase was the result of an increase in cattle sizes, which more than offset a slight decrease in cattle and swine populations. There has also been a shift of swine populations to larger livestock operations, which are believed to be more likely to manage waste using liquid systems that tend to promote methane generation.[61] EIA does not have sufficient data to substantiate that belief at this time. If true, however, it would likely change the trend in emissions from this source from flat to slightly positive (see box on page 43). Estimated 2001 emission levels were approximately 0.39 million metric tons above 1990 levels due to a general increase in the size of cattle over the past decade and an 11-percent increase in the population of market swine.

Rice Cultivation

Estimated methane emissions from U.S. rice cultivation rose to 0.48 million metric tons in 2001 from 0.45 million

[60] U.S. Department of Agriculture, National Agricultural and Statistics Service, Livestock, web site www.nass.usda.gov:81/ipedb.
[61] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1999*, EPA-236-R-01-001 (Washington, DC, April, 2001), p. 5-6, web site www.epa.gov.

Potential Effects of a Shift in Swine Farm Size

The U.S. Department of Agriculture's Census of Agriculture showed a shift in farm size distribution for the management of swine from smaller to larger farms between the 1992 and 1997 census. It is possible that the shift to larger farm sizes has resulted in the increased use of liquid systems to manage swine waste. Generally, liquid management of animal waste leads to increased methane emissions; however, methane emissions from liquid systems are subject to a great deal of variability due to specific conditions. In fact, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, published by the Intergovernmental Panel on Climate Change,[a] provides a default range of methane conversion factors for anaerobic lagoon systems of 0 percent to 100 percent. Given that range of uncertainty, and because it has not been possible to document a continued shift to larger farms since 1997, EIA has not tried to capture the effects of the apparent shift toward larger farms for swine management in its estimate of methane emissions from agricultural sources.

[a]IPCC National Greenhouse Gas Inventories Programme, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (J. Penman, D. Kruger, et al., editors) (Tokyo, Japan: Institute for Global Environmental Strategies, 2000).

metric tons in 2000. The increase was the result of a 9-percent rise in the number of acres harvested. Arkansas, Mississippi, Louisiana, and Texas all saw substantial increases in acres harvested. Methane emissions from rice cultivation in 2001 were 18 percent higher than in 1990 (Table 13).

Burning of Crop Residues

Crop residue burning, being the smallest contributor to agricultural greenhouse gas emissions, represents less than 0.2 percent of total U.S. methane emissions. Estimated 2001 methane emissions from the burning of crop residues were 0.04 million metric tons, down by 2.3 percent from 2000 levels but still 8.6 percent above 1990 levels (Table 13). The small decrease is attributable mainly to declines in corn, wheat, sugar beet, and potato production.

Industrial Sources

U.S. Methane Emissions from Industrial Sources, 1990-2001

Estimated 2001 Emissions (Million Metric Tons Methane)	0.1
Change Compared to 2000 (Million Metric Tons Methane)	*
Change from 2000 *(Percent)*	*-11.7%*
Change Compared to 1990 (Million Metric Tons Methane)	*
Change from 1990 *(Percent)*	*-4.1%*

*Less than 0.05 million metric tons.

Chemical Production

The preliminary estimate of methane emissions from U.S. chemical production in 2001 is 0.064 million metric tons, 10.8 percent less than in 2000 and the lowest level since 1993. The decrease was attributable to drops in ethylene and styrene production. Methane emissions from chemical production, however, are still 15.8 percent above their level in 1990 (Table 22).

Iron and Steel Production

With production of pig iron and coke dropping, methane emissions from iron and steel production fell by 12.8 percent between 2000 and 2001, to the lowest levels in more than 20 years. Emissions in 2001, at 0.048 million metric tons, were 21.9 percent below the 1990 level of 0.062 million metric tons (Table 22).

Table 13. U.S. Methane Emissions from Anthropogenic Sources, 1990-2001
(Million Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Energy Sources												
Coal Mining	4.22	4.08	3.99	3.41	3.47	3.63	3.21	3.24	3.29	3.12	2.98	2.78
Natural Gas Systems	5.60	5.83	5.89	5.88	5.89	5.98	6.00	6.01	6.02	6.19	6.36	6.11
Petroleum Systems	1.30	1.31	1.27	1.21	1.18	1.17	1.15	1.14	1.11	1.04	1.03	1.03
Stationary Combustion	0.56	0.59	0.62	0.54	0.53	0.58	0.58	0.44	0.39	0.42	0.44	0.41
Mobile Sources	0.25	0.23	0.24	0.24	0.24	0.25	0.24	0.24	0.24	0.26	0.25	0.25
Total Energy Sources	**11.94**	**12.04**	**12.01**	**11.27**	**11.31**	**11.62**	**11.18**	**11.07**	**11.05**	**11.02**	**11.06**	**10.58**
Waste Management												
Landfills	11.21	11.07	10.91	10.68	10.39	10.17	9.65	9.19	8.70	8.42	7.85	7.96
Wastewater Treatment	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17
Total Waste Management	**11.36**	**11.23**	**11.07**	**10.84**	**10.55**	**10.33**	**9.80**	**9.35**	**8.86**	**8.59**	**8.02**	**8.13**
Agricultural Sources												
Enteric Fermentation	5.13	5.31	5.39	5.46	5.59	5.60	5.41	5.36	5.36	5.41	5.57	5.59
Animal Waste	2.69	2.79	2.81	2.87	2.97	2.97	2.95	3.10	3.11	3.05	3.07	3.08
Rice Cultivation	0.40	0.40	0.45	0.41	0.48	0.44	0.41	0.45	0.47	0.50	0.45	0.48
Crop Residue Burning	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.04
Total Agricultural Sources	**8.26**	**8.53**	**8.69**	**8.77**	**9.09**	**9.05**	**8.81**	**8.95**	**8.99**	**9.00**	**9.13**	**9.19**
Industrial Processes	**0.12**	**0.11**	**0.12**	**0.12**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**	**0.11**
Total	**31.68**	**31.91**	**31.88**	**31.00**	**31.07**	**31.13**	**29.93**	**29.50**	**29.03**	**28.74**	**28.33**	**28.02**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001). Totals may not equal sum of components due to independent rounding.

Sources: EIA estimates presented in this chapter. Emissions calculations based on Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 4.83-4.84, web site www.ipcc.ch/pub/guide.htm; and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (Washington, DC, various years), web site www.epa.gov.

Table 14. U.S. Methane Emissions from Coal Mining and Post-Mining Activities, 1990-2001
(Million Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Surface Mining												
Mining	0.43	0.42	0.42	0.42	0.45	0.45	0.46	0.47	0.49	0.50	0.49	0.53
Post-Mining	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05
Underground Mining												
Ventilation (Gassy Mines)	2.13	2.04	2.10	1.82	1.85	1.91	1.71	1.79	1.80	1.76	1.67	1.49
Ventilation (Nongassy Mines)	0.03	0.03	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.03
Degasification Systems	1.26	1.23	1.17	1.05	1.06	1.21	1.02	1.06	0.95	0.79	0.87	0.82
Post-Mining	0.64	0.61	0.61	0.53	0.60	0.60	0.62	0.63	0.63	0.59	0.56	0.56
Methane Recovery for Energy (-)	0.29	0.29	0.37	0.47	0.56	0.60	0.67	0.80	0.67	0.61	0.70	0.70
Net Emissions	**4.22**	**4.08**	**3.99**	**3.41**	**3.47**	**3.63**	**3.21**	**3.24**	**3.29**	**3.12**	**2.98**	**2.78**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001). Totals may not equal sum of components due to independent rounding.

Sources: Coal production numbers from Energy Information Administration, *Coal Production*, DOE/EIA-0118 (Washington, DC, various years), and *Coal Industry Annual*, DOE/EIA-0584 (Washington, DC, 1995-2000). Methane recovery rates from U.S. Environmental Protection Agency, Office of Air and Radiation, Non-CO2 Gases and Sequestration Branch, Coalbed Methane Outreach Program. Ventilation data for 1985, 1988, and 1990 provided by G. Finfinger, U.S. Department of the Interior, Bureau of Mines, Pittsburgh Research Center. Ventilation data for all other years provided by U.S. Environmental Protection Agency, Office of Air and Radiation, Non-CO2 Gases and Sequestration Branch, Coalbed Methane Outreach Program.

Table 15. U.S. Methane Emissions from Natural Gas Systems, 1990-2001
(Million Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Production	1.47	1.49	1.49	1.51	1.55	1.57	1.58	1.65	1.67	1.62	1.64	1.66
Gas Processing	0.65	0.71	0.70	0.71	0.71	0.72	0.73	0.71	0.69	0.70	0.71	0.68
Transmission and Storage	2.10	2.21	2.23	2.15	2.11	2.14	2.11	2.05	2.00	2.06	2.18	1.94
Distribution	1.39	1.42	1.47	1.51	1.53	1.55	1.58	1.59	1.66	1.80	1.83	1.83
Total	**5.60**	**5.83**	**5.89**	**5.88**	**5.89**	**5.98**	**6.00**	**6.01**	**6.02**	**6.19**	**6.36**	**6.11**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001). Totals may not equal sum of components due to independent rounding.

Sources: National Risk Management Research Laboratory, *Methane Emissions From the Natural Gas Industry*, Vol. 2, Technical Report, GRI-94/0257.1 and EPA-600-R-96-08 (Research Triangle Park, NC, June 1996), Appendix A; American Gas Association, *Gas Facts* (various years); Energy Information Administration, *Natural Gas Annual,* DOE/EIA-0131 (various years); Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(2002/07) (Washington, DC, July 2002); Energy Information Administration, *Petroleum Supply Annual*, DOE/EIA-0340 (Washington, DC, various years).

Table 16. U.S. Methane Emissions from Petroleum Systems, 1990-2001
(Million Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Refineries	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Exploration and Production	1.26	1.27	1.23	1.17	1.14	1.13	1.11	1.11	1.07	1.01	1.00	1.00
Crude Oil Transportation	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total	**1.30**	**1.31**	**1.27**	**1.21**	**1.18**	**1.17**	**1.15**	**1.14**	**1.11**	**1.04**	**1.03**	**1.03**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001). Totals may not equal sum of components due to independent rounding.

Sources: U.S. Environmental Protection Agency, Office of Air and Radiation, *Draft Estimates of Methane Emissions from the U.S. Oil Industry* (Draft Report, Washington, DC); Energy Information Administration, *Petroleum Supply Annual*, DOE/EIA-0340 (Washington, DC, various years); and *Oil and Gas Journal*, Worldwide Refining Issue and Pipeline Economics Issue (various years).

Table 17. U.S. Methane Emissions from Stationary Combustion Sources, 1990-2001
(Thousand Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Residential												
Coal	*	*	*	*	*	*	*	*	*	*	*	*
Fuel Oil[a]	4	4	4	5	4	4	5	4	4	4	4	4
Natural Gas	4	4	5	5	5	5	5	5	4	5	5	5
LPG	*	*	*	*	*	*	1	1	1	1	1	1
Wood	512	541	569	483	474	526	525	382	341	365	382	359
Total	**521**	**550**	**578**	**493**	**483**	**535**	**535**	**392**	**350**	**374**	**392**	**369**
Commercial												
Coal	1	1	1	1	1	1	1	1	1	1	1	1
Fuel Oil[a]	1	1	1	1	1	1	1	*	*	*	*	*
Natural Gas	3	3	3	3	3	4	4	4	4	4	4	4
LPG	*	*	*	*	*	*	*	*	*	*	*	*
Wood	*	*	*	*	*	*	*	*	*	*	*	*
Total	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**6**	**5**	**5**	**5**	**5**
Industrial												
Coal	7	6	6	6	6	6	6	6	6	5	5	5
Fuel Oil[a]	1	1	1	1	1	1	1	1	1	1	1	1
Natural Gas	11	12	12	13	13	14	14	14	13	12	13	12
LPG	2	2	3	2	3	3	3	3	3	3	3	3
Wood	4	4	4	4	4	4	5	5	4	4	4	4
Total	**26**	**25**	**26**	**27**	**27**	**28**	**28**	**28**	**27**	**26**	**27**	**25**
Electric Power												
Coal	10	10	10	10	10	10	11	11	12	12	12	12
Fuel Oil[a]	1	1	1	1	1	*	*	1	1	1	1	1
Natural Gas	*	*	*	*	*	*	*	*	*	*	*	*
Wood	*	*	*	*	*	*	*	*	*	*	*	*
Total	**11**	**11**	**11**	**11**	**11**	**11**	**12**	**12**	**13**	**13**	**13**	**13**
Total All Fuels												
Coal	17	17	17	17	17	17	18	18	18	18	18	18
Fuel Oil[a]	7	7	7	7	7	7	7	6	6	6	6	6
Natural Gas	19	20	20	21	21	22	23	23	22	21	22	21
LPG	3	3	3	3	3	3	4	4	3	4	4	4
Wood	516	544	573	487	478	530	529	387	346	370	386	363
Total	**563**	**591**	**620**	**536**	**527**	**580**	**581**	**438**	**395**	**418**	**437**	**412**

*Less than 500 metric tons of methane.
P = preliminary data.
[a]Fuel oil use in the residential sector consists of distillate fuel only. In the other sectors it includes both distillate and residual fuel oil.
Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001). Totals may not equal sum of components due to independent rounding.
Sources: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, *Compilation of Air Pollutant Emission Factors*, AP-42, web site www.epa.gov/ttn/chief; Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), web site www.ipcc.ch/pub/guide.htm; and Energy Information Administration, *State Energy Data Report 1998*, DOE/EIA-0214(98) (Washington, DC, September 2000), *Monthly Energy Review*, DOE/EIA-0035(2002/07) (Washington, DC, July 2002), and *Annual Energy Review 2001*, DOE/EIA-0384(2001) (Washington, DC, November 2002).

Table 18. U.S. Methane Emissions from Mobile Sources, 1990-2001
(Thousand Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Motor Vehicles												
Passenger Cars	142	132	131	126	117	109	107	105	105	106	101	101
Buses	1	1	1	1	1	1	1	1	1	1	1	1
Motorcycles	4	4	4	4	4	4	4	4	4	4	4	5
Light-Duty Trucks	63	63	63	75	85	99	92	91	91	108	100	99
Other Trucks	12	12	12	13	14	14	15	15	16	17	16	17
Total	**222**	**212**	**212**	**219**	**221**	**228**	**219**	**217**	**217**	**236**	**223**	**223**
Other Transport	23	23	24	22	22	23	23	21	21	21	24	27
Total Transport	**245**	**235**	**235**	**241**	**243**	**250**	**242**	**238**	**238**	**257**	**247**	**250**

P = preliminary data.

Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001).

Sources: Calculations based on vehicle miles traveled from U.S. Department of Transportation, *Federal Highway Statistics*, various years, Table VM-1. Vehicle emissions coefficients from Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 1.65-1.75, web site www.ipcc.ch/pub/guide.htm. Distribution of passenger car and light duty truck fleet model years for 1983, 1985, 1988, 1991, 1994, and 1997 according to data in the Energy Information Administration's "Residential Transportation Energy Consumption Surveys" for those years. Distribution for passenger cars and light-duty trucks in other years computed by interpolation. Distribution of bus and other truck fleet according to model year computed assuming 10-percent attrition per annum of pre-1983 fleet for each year after 1984.

Table 19. U.S. Methane Emissions from Landfills, 1990-2001
(Million Metric Tons Methane)

Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Gross Emissions from Landfills	12.2	12.3	12.4	12.5	12.6	12.6	12.6	12.6	12.6	12.6	12.7	12.8
Methane Recovered for Energy (-)	0.8	0.8	0.9	0.9	1.1	1.1	1.3	1.6	1.9	2.2	2.5	2.5
Methane Assumed Flared (-)	0.2	0.4	0.7	0.9	1.1	1.3	1.7	1.8	2.0	2.0	2.4	2.4
Net Emissions	**11.2**	**11.1**	**10.9**	**10.7**	**10.4**	**10.2**	**9.6**	**9.2**	**8.7**	**8.4**	**7.8**	**8.0**

P = preliminary data.

Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001).

Sources: Municipal solid waste landfilled from "Nationwide Survey: The State of Garbage in America," *Biocycle* (various years) for years before 2001. Waste generation for 2001 estimated on the basis of annual economic growth. Emissions calculations based on S.A. Thorneloe et al., "Estimate of Methane Emissions from U.S. Landfills," Prepared for the U.S. Environmental Protection Agency, Office of Research and Development (April 1994), and D. Augenstein, "The Greenhouse Effect and U.S. Landfill Methane," *Global Environmental Change* (December 1992), pp. 311-328. Methane recovered and flared from U.S. Environmental Protection Agency, Office of Air and Radiation, Non-CO2 Gases and Sequestration Branch, Landfill Methane Outreach Program, web site www.epa.gov/lmop/.

Table 20. U.S. Methane Emissions from Enteric Fermentation in Domesticated Animals, 1990-2000
(Million Metric Tons Methane)

Animal Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Cattle	4.84	5.02	5.10	5.18	5.31	5.33	5.16	5.10	5.11	5.16	5.33	5.35
Sheep	0.08	0.09	0.09	0.09	0.09	0.09	0.08	0.09	0.09	0.09	0.09	0.09
Pigs	0.15	0.15	0.14	0.13	0.13	0.12	0.11	0.10	0.10	0.09	0.09	0.09
Goats	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Horses	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05
Total	**5.13**	**5.31**	**5.39**	**5.46**	**5.59**	**5.60**	**5.41**	**5.36**	**5.36**	**5.41**	**5.57**	**5.59**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001). Totals may not equal sum of components due to independent rounding.

Sources: Cattle, sheep, and pig population data provided by the U.S. Department of Agriculture, National Agricultural Statistics Service, Livestock, Dairy and Poultry Service. Goat and horse population figures extrapolated from U.S. Department of Commerce, Bureau of the Census, *Census of Agriculture*, 1982, 1987, 1992, and 1997. Emissions calculations based on U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1998*, EPA-236-R-00-001 (Washington, DC, April 2000), web site www.epa.gov; and P.J. Crutzen, I. Aselmann, and W.S. Seiler, "Methane Production by Domestic Animals, Wild Ruminants, Other Herbivorous Fauna, and Humans," *Tellus*, Vol. 38B (1986), pp. 271-284.

Table 21. U.S. Methane Emissions from the Solid Waste of Domesticated Animals, 1990-2001
(Thousand Metric Tons Methane)

Animal Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Cattle												
Beef Cattle	249	264	271	278	284	286	275	275	273	275	280	281
Dairy Cattle	917	923	927	964	1,011	1,045	1,073	1,105	1,112	1,119	1,137	1,150
Swine												
Market Swine	861	912	924	919	975	951	916	1,002	1,026	982	981	977
Breeding Swine	487	515	506	510	501	485	471	498	478	447	449	444
Poultry												
Layers	83	84	86	88	90	91	92	94	97	100	102	104
Broilers	73	77	81	91	95	100	102	105	106	110	104	105
Other Animals												
Sheep	5	5	5	5	4	4	4	4	4	3	3	3
Goats	1	1	1	1	1	1	1	1	1	1	1	1
Horses	12	11	11	11	12	12	13	13	13	14	14	14
Total	**2,688**	**2,792**	**2,812**	**2,867**	**2,973**	**2,974**	**2,946**	**3,095**	**3,111**	**3,049**	**3,071**	**3,080**

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001). Totals may not equal sum of components due to independent rounding.

Sources: Population data for horses and goats extrapolated from U.S. Department of Commerce, Bureau of the Census, *Census of Agriculture*, 1982, 1987, 1992, and 1997. Population data for all other animals from U.S. Department of Agriculture, National Agricultural Statistics Service, Livestock, Dairy and Poultry Branch. Typical animal sizes from U.S. Environmental Protection Agency, Office of Air and Radiation, *Anthropogenic Methane Emissions in the United States: Estimates for 1990, Report to Congress* (Washington, DC, April 1993), p. 6-8. Cattle sizes adjusted by annual slaughter weight from U.S. Department of Agriculture, National Agricultural Statistics Service, Livestock, Dairy and Poultry Branch. Maximum methane production, and waste management systems used from L.M. Safley, M.E. Casada, et al., *Global Methane Emissions from Livestock and Poultry Manure* (Washington, DC: U.S. Environmental Protection Agency, February 1992), pp. 24-27, and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1998*, EPA-230-00-001 (Washington, DC, April 2000). General methane conversion factors from Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), p. 4.25, web site www.ipcc.ch/pub/guide.htm. State methane conversion factors for dairy cattle from U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1998*, EPA-236-R-00-001 (Washington, DC, April 2001), web site www.epa.gov.

Table 22. U.S. Methane Emissions from Industrial Processes, 1990-2001
(Thousand Metric Tons Methane)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	P2001
Chemical Production												
Ethylene	17	18	19	19	20	21	22	23	23	25	23	20
Ethylene Dichloride	3	2	3	3	3	3	3	4	4	4	4	3
Styrene	15	15	16	18	20	21	22	21	21	22	20	16
Methanol	8	8	7	10	10	10	11	12	11	11	9	9
Carbon Black	14	13	15	16	16	17	17	17	18	18	17	16
Total	**56**	**57**	**60**	**66**	**70**	**72**	**75**	**77**	**77**	**80**	**72**	**64**
Iron and Steel Production												
Coke[a]	11	9	9	9	8	9	8	7	7	6	7	6
Sinter	6	5	6	6	6	6	6	6	5	6	5	5
Pig Iron	45	40	43	43	44	46	44	45	43	42	43	38
Total	**62**	**54**	**57**	**58**	**59**	**61**	**59**	**58**	**56**	**54**	**55**	**48**
Total Industrial Processes	**117**	**111**	**117**	**124**	**129**	**132**	**134**	**134**	**133**	**133**	**127**	**112**

[a]Based on total U.S. production of metallurgical coke, including non-iron and steel uses.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2000*, DOE/EIA-0573(2000) (Washington, DC, November 2001). Totals may not equal sum of components due to independent rounding.

Sources: American Iron and Steel Institute, *Annual Statistical Report* (Washington, DC, various years); American Chemical Council (formerly the Chemical Manufacturers Association), *U.S. Chemical Industry Statistical Handbook* (Washington, DC, various years); and Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), p. 2.23, web site www.ipcc/pub/guide.htm.